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(54) Title of the Invention: OPTICAL DEFLECTING ELEMENT

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Specifications

Title of the Invention: Optical Deflecting Element

Scope of the Patent's Claims:

1. An optical deflecting element, characterized by the fact that it comprises a spring part moving in multiple directions different from each other, formed in the surface of one substrate; a mobile part which can be moved without mutual restrictions; and a reflection mirror formed on this mobile part formed by said mobile part;

forming an electric or magnetic means driving said mobile part.

2. The optical deflecting element described in claim 1, wherein said substrate is made of a semiconductor monocrystal, characterized by the fact a two-dimensional construction enables rotational oscillations wherein orthogonal axes which cross each other on the surface of said substrate serve as support points of said mobile part.

3. The optical deflecting element described in claim 1 or 2, characterized by the fact that a conductive coil pattern is formed on said mobile part as a means driving said mobile part.

Detailed Explanation of the Invention
(Sphere of Industrial Use)

This invention relates to an optical deflection scanning element, in particular to deflection scanning of a galvano mirror provided with an optical mechanism.

(Background of This Invention)

Optical deflection scanning elements which have been developed according to prior art methods can use (I) the mechanical method, (II) the electro-optical method, and (III) the acoustic-optical method, etc., in order to generate required characteristics according to each method for various types of devices, from displays or printers to optical memory.

The mechanical method is based on oscillation or rotation of a mirror or a prism and this type of element represents the most traditional type of element. However, because the deflection angle is large, a large number of resolution points must be used and the problem is that this will inevitably cause a small optical loss. That is why this method is used mainly for displays and printers where it at this point still represents the main trend.

Since a method that uses a revolving mirror enables high-speed scanning with a large deflection angle through a polygon mirror based on high-precision processing with a high speed of motor revolutions, this method is used for practical applications in laser printers (LBP).

However, since the revolutions will be in this case one-dimensional, at least two revolving mirrors are required to conduct two dimensional scanning.

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Given that a revolving mirror per se is an expensive unit and this unit is indispensable for high precision processing performed with a polygonal mirror, the deflection scanning system will be also expensive.

On the other hand, various types of oscillating mirror (galvano mirror) designs which have been proposed most recently for application with high-precision processing techniques used for photo-engraving developed in the field of semiconductor processing use a compact size with a high speed of the response. However, because the scanning direction according to all of these proposals is one-dimensional, not only are two elements required in order to conduct two-dimensional scanning, but another problem is that an adjustment of the scanning balance is also required. This means that the above mentioned deflection scanning system is also expensive.

(Purpose of This Invention)

The purpose of this invention is to provide a galvano mirror which enables two-dimensional scanning with one element.

(Invention Summary)

This most important characteristic of this invention is a construction wherein a galvano mirror is supported by a gimbal spring. This gimbal spring can be realized for instance by using photo-engraving of an Si substrate. In addition, a metallic film can be formed for the mirror on the Si substrate by vapor deposition, etc. Two-dimensional deflection scanning can realized for instance by applying a magnetic field in two directions Y, Y during a state when an electric current flows through a thin film coil after vapor deposition or plate has been applied to a mirror surface, so that respective independent changes are realized in response to the detected amount of this magnetic field. The following is a detailed explanation of this invention which is based on its embodiment.

Figure 1 explains the principles of the construction of this invention.

Substrate 1 is formed from an Si monocrystal processed by photo-engraving to create a gimbal spring shape. Gimbal spring 2 has a central rotational axis 5 in direction X as well as axis 6 in direction Y, enabling independent rotational oscillations around respective axes. Thin film coil 4 and galvano-mirror 3 are shaped by plating, etc., or by applying vapor deposition of a metallic film, etc., to a mobile part surface in the center of substrate 1 which is supported by gimbal spring 2. When a constant electric current is applied to thin film coil 4, as a result of independent changes of magnetic field 8 in direction Y and of magnetic field 7 in direction X, the

element will perform rotational oscillations independently along central axis 6 and along axis 5 under the influence of electromagnetic force. Accordingly, when incident beams are introduced from a constant direction to a galvano mirror formed in this element, the light reflected from mirror 3 can be deflected in two dimensions according to the detected amount.

Specifically, the changes of signal amount F (X, Y) having two variables Y and Y are detected by one element, enabling deflection scanning of light beams corresponding to the output of the light.

(Embodiment of the Invention)

Figure 2 shows one embodiment of a concrete construction realized on the basis of the above described principles of this invention.

As shown in the same figure, 1 indicates a monocrystal substrate formed from n-type Si having surface orientation (100). Substrate 1 is processed to form the desired gimbal spring structure fulcra (supporting points) 12 - 12' and 13 - 13' according to the chemical engraving method and photo-engraving method, representing a common IC technique. During this engraving processing, mirror 3, etc., can be formed for instance so that the surface to be formed is coated with a corrosion-resistant resin for protection, and after patterning processing has been conducted according to the photo-sensitive method, etc., by using an SiO_3 film or a photosensitive corrosion-resistant resin, etc., on the reverse surface, anisotropic selection etching is conducted with KOH or a similar alkali solvent.

According to this method, the galvano element is separated into a fixed part (substrate 1) and a mobile part 1'. The size of this mobile part 1' will have an influence on the operating capability of the galvano element.

Specifically, when there is a large damping effect of mobile part 1', a large surface area of mobile part 1' can be created for a large air resistance. On the other hand, when deflection scanning is conducted with a high speed, the mass of mobile part 1` must be reduced. Accordingly, the design must correspond to the use of this galvano element. For example in the case of a directional design of a precision measuring instrument, the flat impact type of the damping effect is considered important. In case of directional characteristics of a display, etc., it is essential to take into consideration the importance of the inertial driving type of operations for high-speed scanning.

The operating speed of this mobile part will be also subject to atmospheric influences on the periphery of the galvano element design. An extremely high speed can be achieved for example if the mobile part is used in a vacuum, and optimal damping characteristics will be displayed if it is used in a fluid which has a specific viscosity. Accordingly, when the operating speed must be controlled with precision, it is necessary to provide an optimal adjustment of the pressure depending on the type of the peripheral fluid of the galvano element.

Mirror 3 can be formed for example with a common type of mirror coating technique using for instance vapor deposition with Ag, Al, Au, etc., or substrate 1 can be used as is by utilizing the mirror polishing method, etc.

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The shape of this mirror should be selected so as to avoid warping due to thermal stress, in particular if the metallic vapor deposition method is used. This can be done for example by selecting a material with a heat expansion coefficient that is only slightly different from that of substrate 1, and it is also necessary to pay attention to an optimal design of the thickness of the thin film which is formed by vapor deposition. Moreover, if substrate 1 is formed with the mirror polishing method, one must make sure that this will not cause any residual mechanical warping.

If the mirror itself is used as an interference filter, a simple color design can be created in order to obtain reflected light with any color of the light rays, for instance by using a flat surface display, etc.

Conductive coil 4 is formed to enable operations on the periphery of mirror 3 having this kind of two-dimensional galvano element. The operations of the galvano element will depend on the torque of the gimbal spring and they will be proportional to the cross-sectional area of conductive coil 4. Accordingly, when conductive coil 4 is formed on the outer side of mirror 3 as shown in the present embodiment, the torque of the gimbal spring can be increased in response to the detected amount (the work input), enabling to realize a two-dimensional design which is characterized by a high sensitivity (deflection angle/detected amount is large).

In order to improve the sensitivity even more, it is necessary either to increase the surface area of mobile part 1', or to increase the value of the electric current which is applied to conductive coil 4. The former method is restricted from the viewpoint of the response characteristics of the gimbal spring, while the latter method is subject to restrictions represented by heat generated by the coil, etc. Under these conditions, it is necessary to choose an optimal design corresponding to the use of the product.

Conductive coil 4 should be formed according to the same method and at the same time with the mirror with vapor deposition of Ag, Al, Au, etc. This makes it possible to simplify the process, as well as to improve the yield and bring down the cost of the design. However, considering that conductive coil 4 is subject to a limitation represented by the generated heat, a thick vapor deposition film is preferable in order to reduce the resistance which should be in the range of multiples of 10 Ω ~ 100 Ω. On the other hand, as was explained above, in order to suppress warping due to the thermal expansion difference between mirror 3 and substrate 1, a thin vapor deposition film is preferable. Given these conditions, it is again necessary to select an optimal method based on the use of the product.

Furthermore, conductive coil 4 is formed with a pattern created according to the photo-engraving method which is a common IC technique on the surface of mobile part 1' of substrate 1. Since in this case, substrate 1 and conductive coil 4 must be electrically insulated, insulating film 10 can be normally formed as shown in the figure from SiO_3 ,etc. To make it possible for this insulating film to suppress warping of mirror 3, one has to take into consideration to a sufficient degree also the heat expansion coefficient, the thickness, etc.

As shown in the same figure, 9 is an electrode pad formed on the substrate (fixed part) 1. Pad 9 can be formed for instance by the wire bonding technique using a wire made of Al, etc., and it can be connected to an external terminal so that an electric current can be applied through pad 9 to conductive coil 4.

Electrode pad 9 can be formed from the same material as conductive coil 4 and it can also be formed at the same time, using vapor deposition, etc., although it does not necessarily have to be formed in this manner or at the same time.

One side of pad 9 is connected through a conductor, for instance a direct metallic conductor, to the outermost shell terminal part 14 of conductive coil 4. In addition, if both items are formed simultaneously and from the same material, it is necessary to create first patterning linking both items according to the photo-engraving method. Moreover, the other side of pad 9 is connected to the innermost shell terminal part 15 of conductive coil 4. Because this connection must cross conductive coil 4, the crossing part must be electrically insulated. As shown in the figure explaining the present embodiment, conductive layer 11 is formed selectively (only in this part) to connect electrically terminal part 9' of the electrode pad to terminal part 15 of conductive coil 4 on the surface of mobile part 1' of substrate 1, and the insulation of the crossing conductive coil 4 can be achieved with a film having insulating characteristics, for instance an SiO_3 film, etc. It is also possible to use another method by utilizing a connecting line made by bonding from an Al wire, etc., so that it reaches to the crossing coil 4. Conductor layer 11 is formed by applying selectively diffusion with an impurity having the opposite polarity than that of substrate 1 (for instance by using boron, etc.).

In addition, if a resistance layer is formed with the diffusion technique in the part having rotation supporting points 12, 12' and 13, 13' on the substrate, the resistance layer can be combined with an angle sensor used simultaneously by the two-dimensional galvano element of this invention with resistance fluctuations corresponding to the torsion angle (shearing strain) caused by the rotations of substrate mobile part 1'.

Figure 3 shows an embodiment relating to the fixing method used to fix the two-dimensional galvano element of this invention. Substrate (fixed part) 1 is connected to base substance 10 as shown in the figure.

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This base substance 10 can be formed for instance from borosilicate glass, etc., which is a material that has a similar thermal expansion coefficient as that of substrate 1, and the electrode connecting method can be used for bonding to substrate 1 without using any adhesive agent.

When this method is used, the residual warping is extremely small and since a deterioration of the connecting layer which is often observed with a common type of adhesive agent will not occur, it is possible to realize a design of the galvano element which ensures a long life span with small fluctuation over time and without warping of mirror 3.

If a fixing method using an adhesive is utilized for this invention, the construction will not necessarily be as shown in Figure 3.

Figure 4 provides a simplified explanation of an application example of the two-dimensional optical deflecting element of this invention. Among concrete application examples of this invention are included a laser beam printer, a projection type TV, a projection type flat-surface display (for instance a liquid crystal display), an optical card memory read/write information device, or a measuring instrument such as an electromagnetic oscillograph, etc. In each case, prior art devices used a plurality of one-dimensional deflecting elements, whereas this invention utilizes a single two-dimensional element. Accordingly, this makes it possible to use the single-stroke writing construction which is shown in Figure 4.

Also, although the explanation of Figure 1 pertained to rotational operations wherein electromagnetic force is applied to mirror part 3 in the present embodiment of this invention, the gist of this invention will not be lost even if electrostatic force is used for this purpose.

Figure 5 shows one embodiment of the galvano element of this element which is operated by electrostatic force. As shown in this figure, base substance 10 is manufactured from a material having a thermal expansion coefficient close to that of substrate 1, for instance borosilicate glass, etc., with a concave part mounted in the center and electrodes 111 ~ 114 deployed along respective edges in four locations. In addition, protrusion 12 is formed to support mobile part 1' of the galvano element in the center of base substance 10. Electrode 11 can be formed easily for instance by vapor deposition, etc. The concave part and the protrusion can be easily realized by using selective chemical etching, etc. Rotational oscillations are induced by electrostatic force between mobile part 1' and electrodes 111,113 and independent rotational oscillations having as its center protrusion 12 are also induced by electrostatic force between mobile part 1' and electrodes 112, 114. This enables two-dimensional scanning in a deflected direction by forming mirror 3 on mobile part 1' which performs these two-dimensional rotational oscillations.

In addition, the magnetic field which is applied in directions X and Y as shown in Figure 1 can be formed for example with an electromagnet and changes of the electromagnetic field can be induced by changing the value of the electric current flowing through the electromagnet.

When electromagnetic driving force is used in two ore more directions for rotational movement in the direction of a single direction, this makes it possible to use a larger deflection angle.

(Effect of the Invention)

The invention makes it possible to obtain two-dimensional deflection scanning with a single element.

Brief Explanation of Figures

Figure 1 is a diagram explaining the principle of this invention, Figure 2 and Figure 3 show a cross-sectional view of one embodiment of this invention, and Figure 4 and Figure 5 are explanatory diagrams explaining the application of this invention.

1 ... substrate, 3 ... mirror, 4 ... conductive coil, 10 ... insulating film, 11 ... conductive layer.

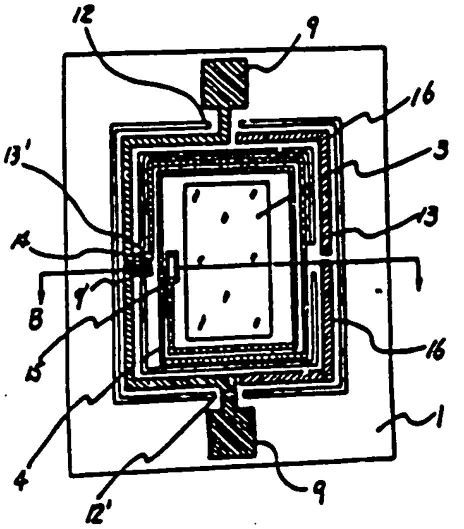
Representative: Akio Takahashi

[Figure 1]

[Figure 1, 2, 3, 4, and 5]

第2図

(a)



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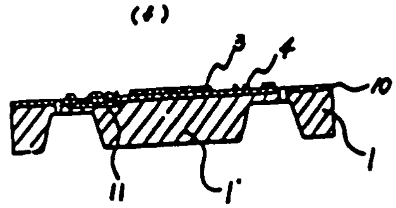

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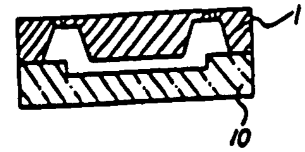
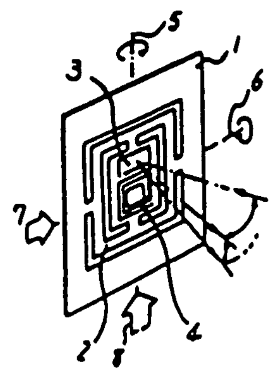
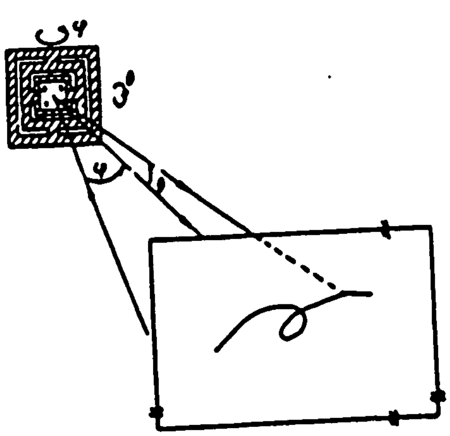


第1図



第4図



第5図

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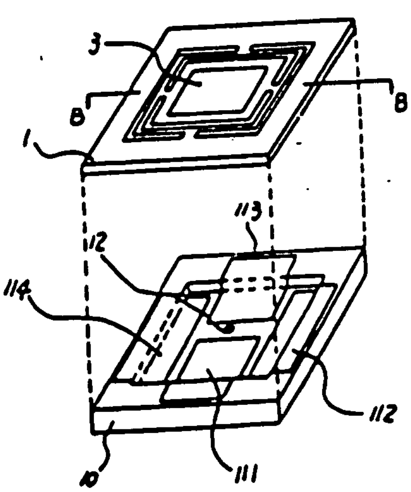

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